

**Final Technical Report on NASA Grant**

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A Program of Cosmic Ray Studies, P.I.s C. J. Waddington and Phyllis S. Freier.  
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Work performed with partial support from this grant is described in the publications listed below:

**Refereed Publications**

- 1 "Intensity of 80- to 200-Mev Protons over Fort Churchill on Aug. 26, 1960," P.S. Freier and C.J. Waddington, J. Geophys. Res. 70, 2111- 2117 (1965).
- 2 "The Helium Nuclei of the Primary Cosmic Radiation as Studied over a Solar Cycle of Activity, Interpreted in Terms of Electric Field Modulation," P.S. Freier and C.J. Waddington, Space Sci. Rev. 4, 313- 372 (1965).
- 3 "Comment on a Paper by G. Kenneth Yates, 'Solar Flare High Energy Alpha Particles and their Storage in Interplanetary Space'," C.J. Waddington and P.S. Freier, J. Geophys. Res. 70, 230-231 (1965).
- 4 "Experimental Observations on the Intensities of Helium Nuclei in the Primary Cosmic Radiation," P.S. Freier, G.D. Greer, J. Valdez, and C.J. Waddington, Phys. Rev. 138, B296-299 (1965).
- 5 "Electrons, Hydrogen Nuclei and Helium Nuclei Observed in the Primary Cosmic Radiation during 1963," P.S. Freier and C.J. Waddington, J. Geophys. Res. 70, 5753-5768 (1965).
- 6 "Paleomagnetic Field Reversals and Cosmic Radiation," C.J. Waddington, Science 158, 913-915 (1967).
- 7 "A New Limit on the Flux of Energetic Gamma Rays from the Radio Source Cassiopeia A," C.J. Waddington, T.C. May, C.D. Lond, J.V. Valdez, and P.S. Freier, Astron. J. 73, 39 (1968).
- 8 "Very Heavy Nuclei in the Primary Cosmic Radiation, I. Observations on the Energy Spectra," P.S. Freier and C.J. Waddington, Phys. Rev. 175, No. 5, pp. 1641-1648, 25 Nov. 1968.
- 9 "The Fragmentation of Cosmic-Ray Nuclei in Interstellar Hydrogen," Astrophys. and Space Sci. 5, 3-17 (1968).
- 10 "Very Heavy Nuclei in the Primary Cosmic Radiation, II. Interpretation of the Energy Spectra," P.S. Freier and C.J. Waddington, Phys. Rev. 175, No. 5, 1649-1658, 25 Nov. 1968.

- 11 "Evidence for the Emission of Energetic Gamma Rays from the Galactic Plane in the Cygnus Region," J.V. Valdez and C.J. Waddington, Ap. J. 156, L85-L89, May (1968).
- 12 "A Search for Energetic Gamma-Ray Emission from the Supernova Remnant Cassiopeia A," T.C. May and C.J. Waddington, Ap. J. 156, 437-444 May (1969).
- 13 "Intensity and Energy Spectrum of Energetic Cosmic Ray Electrons," T.M.K. Marar, Phyllis S. Freier and C.J. Waddington, J. Geophys. Res. 76, 1625-1636 (1971).
- 14 "On the Modulation and Energy Spectrum of Highly Charged Cosmic Ray Nuclei," T.F. Cleghorn, Phyllis S. Freier and C.J. Waddington, Astrophys. and Space Sci. 14, 422-430 (1971).
- 15 "Solar Modulation and the Chemical Composition of the Cosmic Radiation," C.J. Waddington, Nature 236, 391-392, April (1972).
- 16 "Gamma Ray Emission from the Region of the Galactic Center," Dahlbacka, G.H., P.S. Freier and C.J. Waddington, Ap. J. 180, 371 (1973).
- 17 "Computer Simulations of Cosmic Ray Air Showers, II Showers Initiated by Heavy Primary Particles," H.E. Dixon, E.K. Turver and C.J. Waddington, Proc. Roy. Soc. Lond. A., 339, 157 (1974).
- 18 "The Cascading of Cosmic Ray Nuclei in Various Media," Phyllis S. Freier and C.J. Waddington, Astrophys. and Space Sci. 38, 419-436 (1975).
- 19 "Intensity of Primary Cosmic Ray Electrons of Energy Greater than 8 GeV," Phyllis Freier, Charles Gilman and C.J. Waddington, Astrophys. J. 213, 588-598 (1977).
- 20 "A Comment on the Validity of Fragmentation Parameters Measured in Nuclear Emulsions," C.J. Waddington, Astrophysics and Space Sci. 56, 371-375 (1978).
- 21 "The Charge and Energy Spectra of Heavy Cosmic Ray Nuclei," W.R. Scarlett, P.S. Freier and C.J. Waddington, Astrophys. and Space Sci. 59, 301-311 (1978).
- 22 "The Neutron-Rich Isotopes of Cosmic Ray Neon and Magnesium," Phyllis S. Freier, Judy S. Young, and C.J. Waddington, The Astrophysical Journal 240, L53-58, August 15 (1980).
- 23 "The Elemental and Isotopic Composition of Cosmic Rays: Silicon to Nickel," J.S. Young, P.S. Freier, C.J. Waddington, N.R. Brewster, and R.K. Fickle, Ap. J. 246, 1014 (1981).
- 24 "The UH-Nuclei Cosmic Ray Detector on the Third High Energy Astronomy Observatory," W.R. Binns, M.H. Israel, J. Klarmann, W.R. Scarlett, E.C. Stone and C.J. Waddington, Nucl. Inst. and Methods 185, 415 (1981).
- 25 "Cosmic-Ray Abundances of Elements with Atomic Number 26<math>Z</math>140 Measured on HEAO-3," W.R. Binns, R.K. Fickle, T.L. Garrard, M.H. Israel, J. Klarmann, E.C. Stone, and C.J. Waddington, Astro. Journal 247, L115 Aug. (1981).

- 26 "Confirmation of the Anomalous Behavior of Energetic Nuclear Fragments," H.B. Barber, P.S. Freier and C.J. Waddington, Phys. Rev. Lett. 48, 856, March (1982).
- 27 "Nucleus-nucleus collisions and interpretation of cosmic-ray cascades above 100 TeV," T.K. Gaisser, Todor Stanev, Phyllis Freier and C.Jake Waddington, Physical Review D, Vol. 25, No. 9, 1 May (1982).
- 28 "The Abundance of the Actinides in the Cosmic Radiation as Measured on HEAO 3," W.R. Binns, R.K. Fickle, T.L. Garrard, M.H. Israel, J. Klarmann, E.C. Stone, and C.J. Waddington, The Astrophysical Journal, Vol. 261, No. 2, Part 2, 15 October (1982).
- 29 "The Propagation of Ultraheavy Cosmic Ray Nuclei," N.R. Brewster, P.S. Freier, and C.J. Waddington, The Astrophysical Journal 264:324- 336, January 1 (1983).
- 30 "Cosmic-Ray Abundances of Sn, Te, Xe, and Ba Nuclei Measured on HEAO 3," W.R. Binns, R.K. Fickle, T.L. Garrard, M.H. Israel, J. Klarmann, K.E. Krombel, E.C. Stone, and C.J. Waddington, The Astrophysical Journal 267:L93-L96, April 15 (1983).
- 31 "Stopping of 200-GeV gold nuclei in nuclear emulsions," C.J. Waddington, P.S. Freier, and D.J. Fixsen, Physical Review A, Vol. 28, 464 (1983).
- 32 "Exposure of CR-39 Plastic to the Bevalac Mn Beam," Thomas W. Atwater, Phyllis S. Freier, and C.J. Waddington, Nucl. Tracks, Vol. 9, No. 2, pp. 107-111 (1984).
- 33 "Elemental Abundances of Ultraheavy Cosmic Rays," W.R. Binns, D.J. Fixsen, T.L. Garrard, M.H. Israel, J. Klarmann, E.C. Stone and C.J. Waddington, Adv. Space Res., Vol. 4, No. 2-3, pp. 25-34 (1984).
- 34 "The Interactions of Energetic Gold Nuclei in Nuclear Emulsions," C.J. Waddington and P.S. Freier, Phys. Rev. C 31, 388 (1985).
- 35 "The Propagation of Ultraheavy Cosmic Ray Nuclei Revisited," N.R. Brewster, P.S. Freier, and C.J. Waddington, Ap. J. 294, 419 (1985)
- 36 "Lead, Platinum, and Other Heavy Elements in the Primary Cosmic Radiation--HEAO-3 Results," W.R. Binns, N.R. Brewster, D.J. Fixsen, T.L. Garrard, M.H. Israel, J. Klarmann, B.J. Newport, E.C. Stone, and C.J. Waddington, Ap. J. 297, 111 (1985).
- 37 "Stopping Relativistic Xe, Ho, Au and U Nuclei in Nuclear Emulsions," C.J. Waddington, D.J. Fixsen and P.S. Freier, Phys. Rev. A 32, 3102 (1985).
- 38 "Stopping of Relativistic Heavy Ions in Various Media," C.J. Waddington, D.J. Fixsen, H.J. Crawford, P.J. Lindstrom and H.H. Heckman, Phys. Rev. A 34, 3700 (1986).
- 39 "Systematics of the Release of Residual Nuclei from Relativistic Nucleus-Nucleus Interactions," W.R. Binns, T.L. Garrard, M.H. Israel, M.P. Kertzman, J. Klarmann, E.C. Stone, and C.J. Waddington, Phys. Rev. C 36, No. 5, 1870 (1987).

- 40 "Cosmic-Ray Energy Spectra between 10 and Several Hundred GeV per Atomic Mass Unit for Elements from Ar to Ni: Results from HEAO 3," W.R. Binns, T.L. Garrard, M.H. Israel, Michael D. Jones, M.P. Kamionkowski, J. Klarmann, E.C. Stone, and C.J. Waddington, *Ap. J.*, 324, 1106-1117 (1988).

### Conference Reports

- 1 "Modulation of Cosmic Rays by an Electric Field," P.S. Freier and C.J. Waddington, *Proc. 9th Intn'l Conf. on Cosmic Rays, London, Vol. 1*, p. 176 (1965).
- 2 "Electrons, Hydrogen and Helium Nuclei of the Cosmic Radiation as Observed in 1963 and 1964," C.J. Waddington and P.S. Freier, *Proc. 9th Intn'l Conf. on Cosmic Rays, London, Vol. 1*, p. 339 (1965).
- 3 "Low Energy Multiply-Charged Nuclei in the Cosmic Radiation," P.S. Freier, J.S. Rno and C.J. Waddington, *Proc. 9th Intn'l Conf. on Cosmic Rays, London, Vol. 1*, p. 387 (1965).
- 4 "Very Heavy Low Energy Cosmic Ray Nuclei," C.J. Waddington and P.S. Freier, *Proc. 9th Intn'l Conf. on Cosmic Rays, Vol. 1*, p. 390 (1965).
- 5 "The Charge Distribution of the Energetic Very Heavy Nuclei in the Primary Cosmic Radiation," O. Mathiesen, C.E. Long, P.S. Freier and C.J. Waddington, *Can. J. of Phys.* 46, S583 (1968).
- 6 "The Energy Spectrum of the Z m 20 Component of the Cosmic Radiation," P.S. Freier and C.J. Waddington, *Can. J. Phys.* 46, S578 (1968).
- 7 "Energy Dependence of the Fragmentation Parameters and Mean Free Paths of Cosmic Ray Nuclei with Z m 10, T.J. Cleghorn, P.S. Freier and C.J. Waddington, *Can. J. Phys.* 46, S572-577 (1968).
- 8 "The Effects of Solar Modulation on the Energy Spectrum of Heavy Cosmic Ray Nuclei," T.F. Cleghorn, P.S. Freier and C.J. Waddington, *Proc. of the 11th Intn'l Conf. on Cosmic Rays, Budapest (1969)*.
- 9 "The High Energy Electron Component of the Cosmic Radiation," T.M.K. Marar, P.S. Freier and C.J. Waddington, *Proc. of the 11th Intn'l Conf. on Cosmic Rays, Budapest (1969)*.
- 10 "The Charge Spectrum of High and Low Energy Heavy Nuclei in the Cosmic Radiation," C.J. Waddington, P.S. Freier and C.E. Lond, *Proc. of the 11th Intn'l Conf. on Cosmic Rays, Budapest (1969)*.
- 11 "Energetic Gamma Ray Emission from the General Direction of the Cygnus Constellation, J.V. Valdez, P.S. Freier and C.J. Waddington, *Proc. of the 11th Intn'l Conf. on Cosmic Rays, Budapest (1969)*.
- 12 "The Charge and Energy Spectra of Heavy Cosmic Ray Nuclei," P.S. Freier, C.E. Long, T.F. Cleghorn and C.J. Waddington, *Proc. of the 12th Intn'l Conf. on Cosmic Rays, Vol. 1*, 252 (1971).

- 13 "The Cascading of Cosmic Ray Nuclei in the Atmosphere," C.J. Waddington and P.S. Freier, Proc. of Denver Conf. on CR, Vol. 4, 2449 (1973).
- 14 "Intensities of Primary Electron above 10 GeV," P.S. Freier, C.M. Gilman and C.J. Waddington, Proc. of Munich Conf. on CR Vol. 1, 431 (1975).
- 15 "An Observation of the High Charge Cosmic Ray Nuclei," W.R. Scarlett, P.S. Freier and C.J. Waddington, Proc. of Munich Conf. on CR, Vol. 1, 278 (1975).
- 16 "A Chart of Cosmic Ray Isotopes," C.J. Waddington, Proc. of Munich Conf. on CR, Vol. 2, 521 (1975).
- 17 "The Detection of High Charge Cosmic Ray Nuclei," W.R. Scarlett, P.S. Freier and C.J. Waddington, Proc. of Munich Conf. on CR, Vol. 9, 3161 (1975).
- 18 "Detection of the Isotopes of Heavy Cosmic Ray Nuclei," C.M. Gilman and C.J. Waddington, Proc. of Munich Conf. on CR, Vol. 9, 3166 (1975).
- 19 "A Detector of Cosmic Ray Isotopes," P.S. Freier, C.M. Gilman, W.R. Scarlett and C.J. Waddington, Proc. Bulgarian CR Conf. 1, 354 (1977).
- 20 "Cosmic Rays and Clumpy Magnetic Fields," P.S. Freier and C.J. Waddington, Proc. Bulgarian CR Conf. 1, 428 (1977).
- 21 "Nucleus-Nucleus Collisions at a Mean  $E = 20$  GeV/Nucleon," Phyllis S. Freier and C.J. Waddington, Proc. Bartol Conf. 49, 87 (1978).
- 22 "The Charge Distribution of Heavy Cosmic Ray Nuclei," P.S. Freier, J. Young, C.J. Waddington, R. Fickle, C. Gilman, and W.R. Scarlett, Proc. Kyoto CR Conf. 1, 316 (1979).
- 23 "Some Isotopic Abundances in the Cosmic Radiation," J.S. Young, P.S. Freier, and C.J. Waddington, Proc. Kyoto CR Conf. 1, 442 (1979).
- 24 "Interactions of Energetic Heavy Ions with Various Nuclei," K.R.V. Nair, C.J. Waddington and P.S. Freier, Proc. Kyoto CR Conf. 6, 216 (1979).
- 25 "Isotopes of Cosmic Ray Elements from Neon to Nickel," C.J. Waddington, P.S. Freier, and J.S. Young, Origin of Cosmic Rays, published by Reidel Pub. Co., p. 31 (1981).
- 26 "The Heavy Nuclei Experiment on HEAO-3," W.R. Binns, R. Fickle, T.L. Garrard, M.H. Israel, J. Klarmann, E.C. Stone and C.J. Waddington, Ibid., p. 91.
- 27 "On the Detection of Heavy Primaries Above 10TeV," T.K. Gaisser, T. Stanev, P. Freier, and C.J. Waddington, Ibid., p. 71.
- 28 "Abundances of Cosmic Ray Nuclei for  $26 < Z < 40$  from the HEAO-3 Heavy Nuclei Experiment," J. Klarmann, W.R. Binns, M.H. Israel, R.K. Fickle, C.J. Waddington, T.L. Garrard, and E.C. Stone, Proc. of 17th Cosmic Ray Conf., Vol. 2, p. 13 (1981).

- 29 "Abundances of Cosmic Ray Nuclei Heavier than Sn50," C.J. Waddington, R.K. Fickle, T.L. Garrard, E.C. Stone, W.R. Binns, M.H. Israel, and J. Klarmann, *Ibid.*, Vol. 9, p. 109 (1981).
- 30 "Implications of Ultraheavy Cosmic Ray Source Composition Derived from Observations by the HEAO-3 Heavy Nuclei Experiment," M.H. Israel, J. Klarmann, W.R. Binns, R.K. Fickle, C.J. Waddington, T.L. Garrard, and E.C. Stone, *Ibid.*, Vol. 2, p. 36 (1981).
- 31 "The Propagation of UH-Nuclei," N.R. Brewster, P.S. Freier, and C.J. Waddington, *Ibid.*, Vol. 9, p. 126 (1981).
- 32 "The Characteristics of Particles Emitted in Energetic Nucleus- Nucleus Interactions," H.B. Barber, P.S. Freier, and C.J. Waddington, *Ibid.*, Vol. 11, p. 9 (1981).
- 33 "Fragmentation of Iron Nuclei," M. Pofert-Kertzman, P.S. Freier, and C.J. Waddington, *Ibid.*, Vol. 9, p. 187 (1981).
- 34 "Cosmic Ray Elemental Abundances for  $^{26}\text{Zl}^{42}$  Measured on HEAO-3," W.R. Binns, D.P. Grossman, M.H. Israel, M.D. Jones, J. Klarmann, T.L. Garrard, E.C. Stone, R.K. Fickle, and C.J. Waddington, 18th Intn'l CR Conf., Bangalore, India, Vol. 9, p. 106 (1983).
- 35 "Cosmic-Ray Abundances of the Even Charge Elements from Sn to Ce Measured on HEAO 3," E.C. Stone, T.L. Garrard, K.E. Krombel, W.R. Binns, M.H. Israel, J. Klarmann, N.R. Brewster, R.K. Fickle, and C.J. Waddington, 18th Intn'l CR Conf., Bangalore, India, Vol. 9, p. 115 (1983).
- 36 "The Cosmic Ray Abundances of the Platinum-Lead Elements as Measured on HEAO-3," D.J. Fixsen, C.J. Waddington, W.R. Binns, M.H. Israel, J. Klarmann, T.L. Garrard, B.J. Newport, and E.C. Stone, 18th Intn'l CR Conf., Bangalore, India, Vol. 9, p. 119 (1983).
- 37 "Energy Spectra of Ultraheavy Cosmic Ray Results from HEAO-3," M.H. Israel, M.D. Jones, J. Klarmann, W.R. Binns, T.L. Garrard, E.C. Stone, R.K. Fickle, and C.J. Waddington, 18th Intn'l CR Conf., Bangalore, India, Vol. 9, p. 123 (1983).
- 38 "Interactions of 200 GeV Gold Nuclei in Light Elements," N.R. Brewster, R.K. Fickle, C.J. Waddington, W.R. Binns, M.H. Israel, M.D. Jones, J. Klarmann, T.L. Garrard, B.J. Newport, and E.C. Stone, 18th Intn'l CR Conf., Bangalore, India, Vol. 9, p. 259 (1983).
- 39 "Abundances of 'Secondary' Elements Among the Ultraheavy Cosmic Rays - Results from HEAO-3," J. Klarmann, W.R. Binns, M.H. Israel, S.H. Margolis, T.L. Garrard, E.C. Stone, N.R. Brewster, D.J. Fixsen, and C.J. Waddington, 18th Intn'l CR Conf., Bangalore, India, Vol. 9, p. 279 (1983).
- 40 "Correlation of Source Abundances of Ultraheavy Cosmic Rays with First Ionization Potential--Results from HEAO-3," M.H. Israel, W.R. Binns, D.P. Grossman, J. Klarmann, S.H. Margolis, E.C. Stone, T.L. Garrard, K.E. Krombel, N.R. Brewster, R.K. Fickle, and C.J. Waddington, 18th Intn'l CR Conf., Bangalore, India, Vol. 9, p. 305 (1983).

- 41 "The Non-ZResponse of the Heavy Nuclei Cosmic Ray Detector on HEAO- 3," T.L. Garrard, B.J. Newport, E.C. Stone, W.R. Binns, M.H. Israel, M.D. Jones, J. Klarmann, R.K. Fickle, and C.J. Waddington, 18th Intn'l CR Conf., Bangalore, India, Vol. 9, p. 367 (1983).
- 42 "Residual Nuclei from Relativistic Collisions," C.J. Waddington and P.S. Freier, Nucleus-Nucleus Collisions II, Vol. 1:Contributed Papers, p. 22, Edited by B. Jakobsson and K. Aleklett, 2nd Intn'l Conf. on Nucleus-Nucleus Collisions, Visby, Sweden, June (1985).
- 43 "Elemental Abundances of Cosmic Rays with  $Z > 33$  as Measured on HEAO- 3," B.J. Newport, E.C. Stone, C.J. Waddington, W.R. Binns, T.L. Garrard, M.H. Israel, and J. Klarmann, 19th ICRC, La Jolla, CA, Vol. 2, 123 (1985).
- 44 "Energy Spectra of Elements with  $18 \leq Z \leq 28$  between 10 and 300 GeV/amu," M.D. Jones, J. Klarmann, E.C. Stone, C.J. Waddington, W.R. Binns, T.L. Garrard, and M.H. Israel, 19th ICRC, La Jolla, CA, Vol. 2, 28 (1985).
- 45 "Implications of Source Abundances of Ultraheavy Cosmic Rays," W.R. Binns, T.L. Garrard, M.H. Israel, J. Klarmann, S.H. Margolis, E.C. Stone, and C.J. Waddington," 19th ICRC, La Jolla, CA, Vol. 3, 13 (1985).
- 46 "Variations in the Propagation of UH-Nuclei," C.J. Waddington, N.R. Brewster, and M.P. Kertzman, 19th ICRC, La Jolla, CA, Vol. 3, 1 (1985).
- 47 "Interactions of Heavy Nuclei, Kr, Xe and Ho, in Light Targets," M.P. Kertzman, J. Klarmann, B.J. Newport, E.C. Stone, C.J. Waddington, W.R. Binns, T.L. Garrard, and M.H. Israel, 19th ICRC, La Jolla, CA, Vol. 3, 95 (1985).
- 48 "The Response of Ionization Chambers in Relativistic Heavy Nuclei," B.J. Newport, E.C. Stone, C.J. Waddington, W.R. Binns, D.J. Fixsen, T.L. Garrard, G. Grimm, M.H. Israel, and J. Klarmann, 19th ICRC, La Jolla, CA, Vol. 3, 287 (1985).
- 49 "Stopping Relativistic Xe, Ho, Au and U Nuclei in Nuclear Emulsions," C.J. Waddington, D.J. Fixsen and P.S. Freier, 19th ICRC, La Jolla, CA, Vol. 6, 104 (1985).
- 50 "Cosmic ray energy spectra between ten and several hundred GeV/amu for elements from  $^{18}\text{Ar}$  to  $^{28}\text{Ni}$  – Results from HEAO-3", M. H. Israel, Michael D. Jones, M. P. Kamionkowski, J. Klarmann, E. C. Stone, C. J. Waddington, W. R. Binns and T. L. Garrard, 20th ICRC, Moscow, Vol 1, 330 (1987)
- 51 "Anisotropy of galactic iron of energy 30 to 500 GeV/amu studied by HEAO-3, T. L. Garrard, P. S. Gibner, M. H. Israel, J. Klarmann, C. J. Waddington and W. R. Binns, 20th ICRC, Moscow, Vol 1, 348 (1987)
- 52 "The abundances of ultraheavy elements in the cosmic radiation" E. C. Stone, C. J. Waddington, W. R. Binns, T. L. Garrard, P. S. Gibner, M. H. Israel, M. P. Kertzman, J. Klarmann and B. J. Newport, 20th ICRC, Moscow, Vol 1, 366 (1987)

- 53 "The energy dependence of fragmentation cross sections of relativistic heavy nuclei", C. J. Waddington, W. R. Binns, T. L. Garrard, P. S. Gibner, M. H. Israel, M. P. Kertzman and J. Klarmann, 20th ICRC, Moscow, Vol 2, 149 (1987)
- 54 "Release of nuclei from relativistic nucleus-nucleus interactions", C. J. Waddington, W. R. Binns, T. L. Garrard, M. H. Israel, M. P. Kertzman, J. Klarmann and E. C. Stone, 20th ICRC, Moscow, Vol 2, 152 (1987)
- 55 "Response of ionization chambers and Cherenkov counters to relativistic ultraheavy nuclei", J. Klarmann, C. J. Waddington, W. R. Binns, T. L. Garrard, P. S. Gibner and M. H. Israel, 20th ICRC, Moscow, Vol 2, 390 (1987)
- 56 "Nucleus-nucleus interactions at 14.6, 60 and 200 GeV/amu", L. Barbier, P. S. Freier, R. Holynski, A. Jurak, W. V. Jones, A. Olszewski, O. E. Pruett, C. J. Waddington, J. P. Wefel, B. Wilczynska, H. Wilczynski, W. Wolter and B. Wosiek, 20th ICRC, Moscow, Vol 5, 110 (1987)

### Articles

- 1 "Spectral Composition," C.J. Waddington, Proc. 9th Intn'l Conf. on Cosmic Rays, Vol. 1, p. 462 (1965).
- 2 "Some Remarks on the Composition of the Cosmic Radiation," C.J. Waddington, Proc. VI Interamerican Seminar on Cosmic Rays, Vol. I, p. 50 (1971).
- 3 "The Chemical Composition and Energy Content of Energetic Cosmic Radiation," C.J. Waddington, Proc. of the Nat'l Symposium on Natural and Manmade Radiation in Space, NASA TM X-2440, January (1972).
- 4 "Ultraheavy Cosmic Rays," Martin H. Israel, P. Buford Price and C. Jake Waddington, Physics Today 28, May 23 (1975).
- 5 "The Nuclear Particles of the Cosmic Radiation," C.J. Waddington, Fundamentals of Cosmic Physics, Gordon and Breach 3, 1-85 (1977).
- 6 "The Cosmic Ray Nuclides," C.J. Waddington, Rapporteur Report to Bulgarian CR Conf. 10, 168 (1977).
- 7 "UH-Nuclei in the Cosmic Radiation, Present and Future," Proc. of the Workshop on Cosmic Ray and High Energy Gamma Ray Experiments for the Space Station ERA, edited by W.V. Jones and J.P. Wefel, LSU, Baton Rouge, LA (1985).
- 8 "Measurements of Ultraheavy Cosmic Rays with HEAO-3," W.R. Binns, M.H. Israel, J. Klarmann, T.L. Garrard, E.C. Stone, and C.J. Waddington, Essays in Space Science, NASA Conf. Pub. 2464, p. 173 (1987).